AMS-336

Variations in Quality of MARSH GRAPEFRUIT

Marketing Research Division
Agricultural Marketing Service
United States Department of Agriculture

Washington, D.C.

CONTENTS

ACKNOWLEDGMENTS

Acknowledgment is due William H. Henry, former biological aid, T. Adair Wheaton, and Mattie M. C. Welty of the Quality Maintenance and Improvement Section for their assistance in conducting the investigation.

October 1959

VARIATIONS IN QUALITY OF MARSH GRAPEFRUIT

By William G. Long, Paul L. Harding, Mortimer J. Soule, Jr., and Milliard B. Sunday [1]
Biological Sciences Branch, Agricultural Marketing Service

SUMMARY

Investigations of variations in physical and chemical characteristics of Marsh grapefruit were undertaken to find ways by which shippers might be able to harvest and pack a product of higher quality and greater uniformity.

Measurements and analyses were made of 3,800 individual grapefruits for weight, height and diameter, flesh texture, mixing of varieties, volume of juice, total soluble solids, titratable acid, solids-to-acid ratio, ascorbic acid, and active acidity (pH). Some of the existing variations were evaluated.

Fruit weight differed as much as 39 to 50 percent of the average value between the maximum and minimum observed for fall fruit. Spring samples varied from 41 to 61 percent on that basis. The volume of juice varied from 58 to 87 percent of the average value between the lowest and highest values in the fall to 60 to 78 percent in the spring. The range between the minimum and maximum concentrations of total soluble solids differed from 39 to 47 percent of the average value for this size of fall fruit, while spring harvested samples varied from 56 to 88 percent of the average. Differences between the minimum and maximum concentrations of acid ranged from 77 to 93 percent in the fall and from 119 to 131 percent of the average in spring fruit. Differences between the minimum and maximum solids-to-acid ratio were equal to 62 to 95 percent of the averages in the fall and 106 to 181 percent in the spring. Similarly, ascorbic acid varied 51 to 70 percent in the fall and 79 to 92 percent in the spring. Difference in active acidity (pH) of the composited juice was small.

Variations in diameter and height are controlled by the sizing operation. Solids, acid, and ascorbic acid content were inversely related to size. The physical factors of fruit weight, diameter, volume of juice, and texture of flesh are interrelated. No such relation was found for or with solids, acid, solids-to-acid ratio, ascorbic acid, or pH. When volume of juice is plotted against solids, acid, or solids-to-acid ratio, distinct breaks between coarse- or ricey- and good-textured fruit occur. Variations in fruit weight, volume of juice, solids, acid, solids-to-acid ratio, and ascorbic acid were greater among samples than between sizes and greater in spring than in fall fruit. Substantial differences between crop years were found in the constituents.

INTRODUCTION

More than 37 million boxes of grapefruit were produced in Florida during the 1956-57 season (12, 24),[2] with a yearly average of 34 million boxes between 1949 and 1954. Approximately 18 million boxes, including about 10 million boxes of white seedless grapefruit, were shipped as fresh fruit. These fruit were worth in excess of $20 million to the grapefruit growers of Florida, an average on-the-tree-return of $1.42 per box. The total value of the crop as a source of income to related industries and services was much greater.

---

[1] Mr. Long is a horticulturist, Mr. Harding a principal plant physiologist, and Mr. Sunday a technician, with Agricultural Marketing Service, Orlando, Fla. Mr. Soule, Jr., formerly horticulturist with Agricultural Marketing Service, is now associate professor, Department of Fruit Crops, University of Florida.

[2] Underscored figures in parenthesis refer to Literature Cited, p. 25.

The flavor of each fruit is of vital concern since fresh grapefruit is usually consumed in the form of individual whole fruit or halves. Grapefruit must be mature according to existing standards for color, volume of juice, total soluble solids, acid, and solids-to-acid ratio, under the Florida Citrus Code of 1949 as amended, before it can be shipped in commercial channels. The maturity test is based on the analysis of a 5-fruit sample; however, testing of individual fruit is permitted. The ultimate criterion for approval of internal quality of any fruit is its acceptance by the consumer (14). If internal quality of fruit vary sufficiently that some sour- or bitter-tasting grapefruit are shipped, the consumer's buying habits can be adversely affected.

Harding and Fisher (15) reported a delay between the time when grapefruit became legally mature in the fall and when they became palatable. The amount of delay was dependent upon such factors as variety, rootstock, climate, soil, crop year variations, arsenical sprays, and others. Baier (2), Bureau of Agricultural Economics (7), Capel (8), and Provan (21), found that most people do not like a bitter flavor in grapefruit. Bell (4), Branson and associates (6), Bureau of Agricultural Economics (7), and Sinclair and Bartholomew (25), reported that the flavor of grapefruit or grapefruit products is improved when sugar is added. The net result of sugar addition is a higher ratio of total soluble solids to acid and a sweeter more palatable fruit.

External quality of a grapefruit is important. A smooth, bright yellow colored fruit stimulates the initial sale by its pleasing appearance. Repeat sales depend on internal quality and palatability. Consumer prejudice against poor external appearance often can be overcome by education if internal fruit quality is good. It may not be overcome when internal fruit quality and flavor are poor, even if external appearance is excellent.

Baier (2) pointed out that grapefruit from different sections in California and Arizona vary considerably in characteristics at maturity. Hilgeman (17) in Arizona found that the point at which different grapefruits are mature is a variable one. Wood and Reed (29) in Texas pointed out that physical factors were affected more than chemical factors by cultural practices; they favored solids, solids-to-acid ratio, and juice content for determining maturity.

Harding and Fisher (14, 15) in Florida used volume of juice and solids and acid nomographs as bases for determining maturity and palatability. Rygg and Getty (23) concluded that the best standard for grapefruit from California and Arizona was the solids-to-acid ratio. They stated that the relation of palatability to solids-to-acid ratio was not as close as it should be for a good index; the solids and acid nomograph did not always separate palatable and unpalatable grapefruit. The need for an improved index for determination of citrus maturity and of palatability has been cited by many authors (2, 14, 15, 21, 23, 29).

The ratio of solids to acid does not indicate either solids or acid content. The effect of solids and acid upon tartness, sweetness, or the body of flavor is shown by the "Pritchett Graphical Tongue" (3), which was developed for tasting orange juice in California. Percent solids is plotted against solids-to-acid ratio, and the points are enclosed for which the solids and acid were satisfactory to taste. Quality based on an average or composite value seems to be inadequate, since the extremes are the fruits that usually cause difficulty, not those near the average.

The present investigation of individual Marsh seedless grapefruit was undertaken to determine the extent of the variations in physical and chemical characteristics with respect to internal quality and their relationship to external quality. A better understanding of these variations might enable shippers to harvest and pack a more uniform product of substantially higher quality than is possible with existing methods of handling.

METHODS

The investigation was conducted during the seasons of 1953-54, 1954-55, 1956-57, and 1957-58. A total of 3,800 grapefruits in 26 samples were taken at random from the packing bins of 18 packinghouses. The sample consisted of subsamples of 30 Marsh grapefruit each for sizes 46, 54, 64, 70, 80, and 96. These fruit had been washed, polished, waxed, graded, and sized into bins and were ready to be packed into containers for shipment. They were placed in canvas bags and transported to the U. S. Department of Agriculture Horticultural Field Station at Orlando, Fla., and held a few days at 32° F. until tested. Ten of the 26 samples were collected in September and October (fall) and 16 during March, April, and May (spring). The fruit came from the major citrus-producing sections of Florida--central, ridge, and the east and west coasts.

Twenty-five sound fruits were taken at random from each subsample after discarding any which were punctured or bruised in transit. They were numbered and weighed to the nearest gram. The diameter and height were measured to the nearest sixteenth of an inch. Color of the rind was determined by matching the fruit with plate 4 of Harding and Fisher (15). After each fruit was cut in half, the internal texture was classified as ricey, coarse, good, overripe, or dry, according to the definitions of these terms by Harding and Fisher (15).

The pulp and juice of each fruit were separated from the rind with an electric reamer and passed through a tapered-screw finisher equipped with an 0.027-inch screen. The juice was weighed to the nearest gram and measured to the nearest milliliter. Percent total soluble solids was obtained refractometrically. Total acid was determined by titration using phenolphthalein as the indicator, and ascorbic acid was determined by sodium 2,6-dichloroindophenol titration (1, 5). Duplicate samples were analyzed in all cases. Active acidity (pH) was determined on a composite of each subsample.

Representative samples were taste tested and rated by the scorecard used by Harding and Fisher (15). The fall samples were generally tart (60-69), with some pleasantly tart (70-79), while samples were mostly pleasantly tart to sweet (80-100), with some pleasantly tart.

In order to study range and distribution of the chemical and physical measurements and their relation to quality, the data were grouped in classes in relation to the average. (1) Five classes with an interval of 50 g. were established for fruit weight, with the average rounded to the nearest 5 g. as the center of the middle class. (2) Five classes with an interval of 50 ml. were established for juice volume, with the average rounded to 5 ml. as the center of the middle class. (3) Four classes for diameter were defined for each size by using the minimum and maximum values for diameter allowed under the U. S. Grade Standards (20) as the lower limit for class 2 and the upper limit for class 3, with a class interval of one-half the permitted range in diameter. Class 1 contained all of the values falling below the minimum, while class 4 contained all of the values above the maximum. (4) A class interval of 1 percent was used for total soluble solids, (5) 0.20 percent for total acid, and (6) 1 ratio point for solids-to-acid ratio.

RESULTS

Physical Measurements

Weight.--There was a wide variation in weight among individual grapefruit of a given size. For example, it may be seen in table 1 that size 96 fruit harvested in the fall (September and October) weighed from 288 to 451 g., with an average of 365 g., while fruit harvested in the spring (March, April, and May) weighed from 307 to 491 g., with an average 385 g.

TABLE 1.--Weight of Marsh grapefruit, 1953-54, 1954-55, 1956-57, and 1957-58

Fruit size	Fall harvest			Spring harvest		
	Minimum	Maximum	Average	Minimum	Maximum	Average
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
96................	288	451	365	307	491	385
80................	316	547	425	341	561	449
70................	343	575	478	399	605	498
64................	432	643	534	431	662	551
54................	462	726	599	523	813	631
46................	548	894	689	582	1,031	730

When the weight distribution curves for each size were plotted (fig. 1), the average or midclass generally contained the greater proportion of the values. As the fruit sizes increased from size 96 to size 46, there was progressively greater variation in weight as indicated by flatter curves for the larger sizes. Fifty-three percent of the fruits of size 96 were in the average or midclass as compared with 45 percent in size 80, 44 percent in size 70, 48 percent in size 64, 39 percent in size 54, and 27 percent in size 46. An increasing proportion of the fruits was found in the two extreme classes as fruit size increased from size 96 to size 46.

Fruits of size 96 harvested in the fall varied from an extreme of 21 percent below the average to 24 percent above; those of size 80 from 26 percent below to 29 percent above; those of size 70, from 28 percent below to 20 percent above; those of size 64, from 19 percent below to 28 percent above; those of size 54, from 23 percent below to 21 percent above; and those of size 46, from 20 percent below to 30 percent above.

The average weights of Marsh grapefruit harvested in the spring ranged from 20 to 41 g. larger than the fall samples. A small to substantial increase was noted in the percentage of individual fruits in the midclass (fig. 1) for all sizes except 46. The proportion of fruit in classes above and below the midclass was more nearly equal than in the fall samples. The range between minimum and maximum weights was larger by 21 g. for fruit of size 96 and by 103 g. for those of size 46 in the spring samples. On a percentage basis, the range between the minimum and maximum weights of the sizes was from 41 to 61 percent of the average values. Another noticeable difference between the fall and spring samples was the tendency in the fall samples, particularly in sizes 54 and 46, for the maximum weight to deviate more from the average than did the minimum.

Variations in fruit weight ranged from 39 to 50 percent of the average value between the minimum and maximum weights obtained for fruit harvested in the fall. Spring fruit varied from 41 to 61 percent on a similar basis, but the smaller sizes varied more than the larger. This relation was not apparent in the fall.

Harding and Fisher (15) and Rygg and Getty (23) reported increases in weight of grapefruit as the season progresses as well as differences between crop years. Numerous factors, such as rootstock, cultural practices, and so forth, are known to affect fruit weights (2, 14, 15, 18, 22, 26).

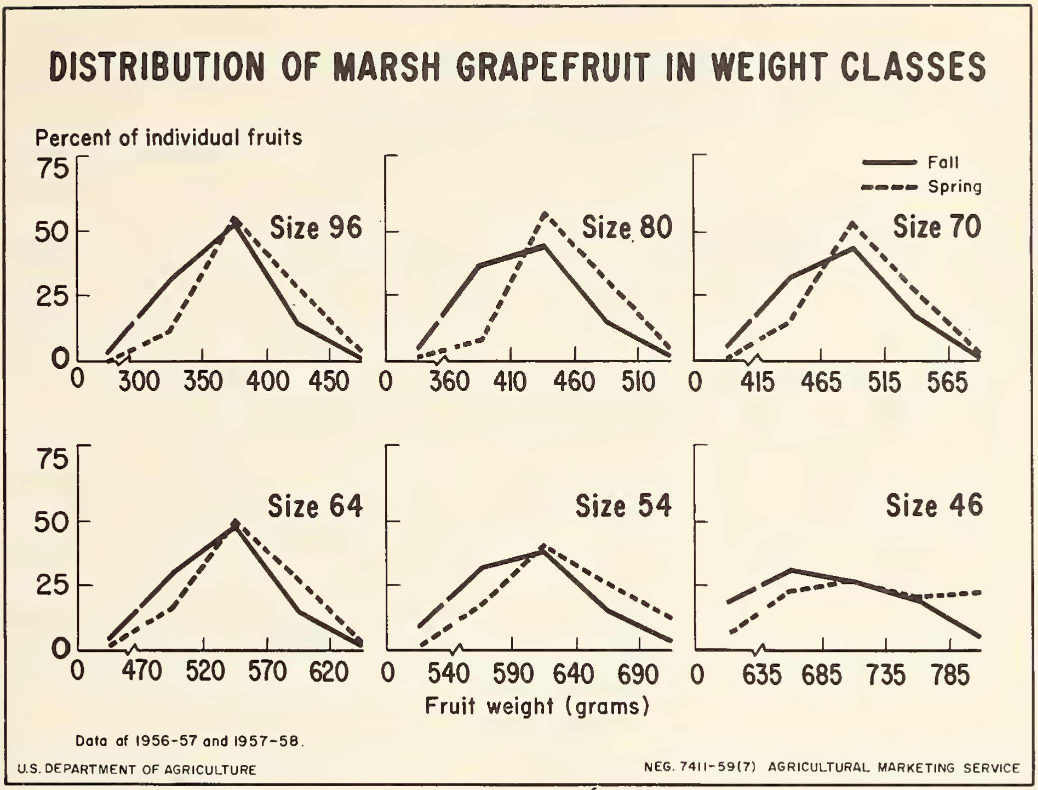

FIGURE 1

Diameter and Height. --The diameters of individual Marsh grapefruit harvested in the fall did not differ more than 12/16 to 14/16 inch depending on the size (table 2). Average diameters calculated for the measurements were essentially the same as the averages given by the regulations of the Florida Citrus Commission (11) (table 2). The U. S. grade requirements were met by most fruit. In a few samples the fruits were smaller than the minimum diameter required or exceeded the tolerance for variability. Less than one-half percent of the fruit was larger in size than the maximum.

The variation of the diameters from the averages (fig. 2) shows that the major proportion of the diameters was in the class above the minimum size. A very small percentage (less than 0.5) was above the maximum, while a few of the fruits of sizes 96, 64, 54, and 46 were below the minimum. Those of sizes 80 and 70 would appear to be sized slightly larger than some of the other sizes, since a greater percent occurred in the top half of the range specified by the U. S. standards than for the other sizes. The larger sizes were somewhat more variable on a numerical basis, but the percent deviation of the minimums and maximums from the averages was similar.

Marsh grapefruit of the spring samples were remarkably similar to those of the fall samples in average diameter and range (table 2) as well as in distribution of individual fruits (fig. 2).

Minimum, maximum, and average heights of fruit harvested in the fall are shown in table 3. The difference between minimum and maximum heights of the different sizes ranged from 12/16 to 1-1/16 inch. The three larger sizes varied most. Fruits of size 96 had a range of 14/16 inch, while those of size 80 had the smallest range, 12/16 inch.

TABLE 2.--Diameter of Marsh grapefruit, 1956-57 and 1957-58, in comparison with U. S. Department of Agriculture and Florida requirements for size of grapefruit

Fruit size	Fall harvest			Spring harvest			Size requirements		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum[1]	Maximum[1]	Average[2]
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
96.........	3-7/16	4-2/16	3-12/16	3-8/16	4-1/16	3-12/16	3-9/16	4-2/16	3-12/16
80.........	3-9/16	4-5/16	3-15/16	3-11/16	4-4/16	4	3-12/16	4-5/16	3-15/16
70.........	3-13/16	4-9/16	4-3/16	3-15/16	4-7/16	4-3/16	3-15/16	4-8/16	4-2/16
64.........	4-1/16	4-12/16	4-6/16	4-1/16	4-10/16	4-5/16	4-3/16	4-12/16	4-6/16
54.........	4-3/16	5-1/16	4-9/16	4-4/16	5-1/16	4-9/16	4-6/16	4-15/16	4-19/32
46.........	4-6/16	5-4/16	4-13/16	4-8/16	5-10/16	4-13/16	4-11/16	5-4/16	4-29/32

1 Adapted from the "U. S. Standards for Florida Grapefruit," U. S. Department of Agriculture, 1952.
2 Adapted from Regulations of the Florida Citrus Commission, 1957.

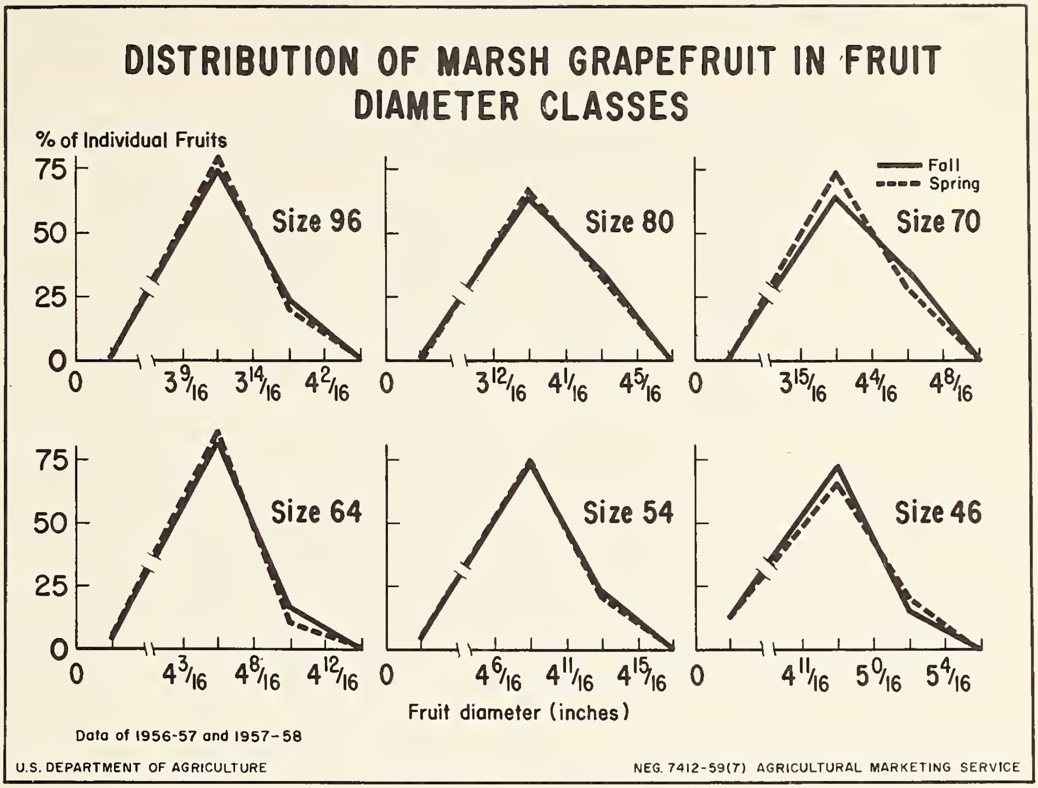

FIGURE 2

Average heights varied from 3-6/16 inches for fruits of size 96 to 4-4/16 inches for those of size 46. Fruits harvested in the spring showed similar results. The presence of some late-bloom fruit in these samples had little effect on the average height or on the range in height. Increases in size of grapefruit as the season progresses have been shown by Harding and coworkers (15, 16) and Rygg and Getty (23). Jones and Parker (18), Reuther and Smith (22), and Sites (26) have shown that fertilization affects size.

Internal Texture and Conditions.--The juiciness and internal quality of a grapefruit are correlated with internal texture and condition. A ricey- or coarse-textured fruit has not yet developed the amount of juice necessary to distend the vesicle walls to the thinness found in a good- or prime-textured one. The majority of the fruits harvested in the fall were coarse in texture. The highest percentage of coarse-textured fruits was 83 percent, found in size 80, and the lowest was 66 percent in size 46 (table 4). The lowest percentage of fruits with ricey texture, 11 percent, was found in sizes 96 and 80, and the highest, 34 percent, in size 46. Twelve percent of the fruits of size 96 were good in texture compared to only 1 percent in size 64, and none in sizes 54 and 46.

Among the samples harvested in the spring, sizes 46 and 54 showed the greatest amount of coarse-textured fruit--14 percent. Sixty-two percent of the fruits of size 46 and from 64 to 71 percent in the other sizes were in the good category. Overripeness ranged from 9 percent in fruits of size 64 to 15 percent in size 46. One or 2 percent dryness was found in all sizes except size 80. Nine percent of the fruits of sizes 96, 80, and 70 were "late-bloom" type compared to 6 percent in size 46.

These data point out some interesting changes in the internal texture of individual fruits as the season progresses. Early in the season the texture of grapefruit improves rather rapidly from ricey to coarse to good, while later in the season the fruit begins to show overripeness and dryness. Fruits of size 46 seemed to be poorer in texture than those of other sizes.

TABLE 3.--Height of Marsh grapefruit, by size of fruit, 1956-57 and 1957-58

Fruit size	Fall harvest			Spring harvest		
	Minimum	Maximum	Average	Minimum	Maximum	Average
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
96....................	3	3-14/16	3-6/16	3	3-13/16	3-6/16
80....................	3-2/16	3-14/16	3-8/16	3-3/16	3-15/16	3-9/16
70....................	3-5/16	4-3/16	3-11/16	3-5/16	4-2/16	3-11/16
64....................	3-7/16	4-8/16	3-14/16	3-8/16	4-4/16	3-14/16
54....................	3-7/16	4-8/16	4-1/16	3-8/16	4-9/16	4-1/16
46....................	3-11/16	4-12/16	4-4/16	3-12/16	4-14/16	4-4/16

TABLE 4.--Percentage of fall and spring harvests of Marsh grapefruit having specified internal texture and conditions by size of fruit, 1953-54, 1954-55, 1956-57, and 1957-58

Fruit size	Fall harvest			Spring harvest					
	Ricey	Coarse	Good	Ricey	Coarse	Good	Over-ripe	Dry	Late-bloom
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
96..........	11	77	12	0	8	71	11	1	9
80..........	11	83	6	1	7	71	12	0	9
70..........	20	78	2	1	10	67	13	1	9
64..........	26	73	1	1	10	71	9	2	7
54..........	22	78	0	0	14	64	13	1	8
46..........	34	66	0	1	14	62	15	2	6

Mixing of Varieties.--The presence of pink (Thompson) or seedy (Duncan) fruit in a packed box of white Marsh seedless grapefruit is not uncommon and might cause unfavorable consumer reaction. A mixture with pink or seedy fruit can result from several causes. Perhaps most frequently it results from failure to clean out the bins between lots of fruit in the packinghouse. It may also arise through having a few off-type trees in the grove. Pink fruit (table 5) were mixed more often with Marsh in sizes 64, 54, and 46 of the fall samples, with the greatest percent occurring in size 46. Zero to 4 percent of seedy fruit were found mixed with the Marsh, with sizes 46 (4 percent) and 96 (3 percent) being the highest. No pink fruit were found in the spring samples, which indicates that the mixture was probably the result of failure to clean out the bins. However, a greater number of seedy fruit was present, particularly in the larger sizes. The pink grapefruit are generally harvested early in the season, whereas seedy fruit are picked more or less throughout the entire crop year.

Juice Volume.--Minimum, maximum, and average juice volumes of Marsh grapefruit harvested in the fall and spring, together with the legal maturity requirements for juice set forth in the Florida Citrus Code of 1949, as Amended, (10) are given in table 6. Fruits of larger size showed a wider range on a volume basis. It was found, however, that the trend was quite different when the deviations from the average for each size were computed on a percentage basis. The difference between the minimum and maximum juice volume of fruits harvested in the fall amounted to 76 percent of the average for size 96; 87 percent for size 80; 62 percent for size 70; 71 percent for size 64; 58 percent for size 54; and 64 percent for size 46. Grapefruit harvested in the spring averaged from 20 to 30 ml. higher in juice volume than the fall samples, and the differences between the minimum and maximum volumes were from 60 to 78 percent of the average. Fruit of the spring samples contained more juice than those picked in the fall, but they were more variable.

TABLE 5.--Percentages of seedy and pink grapefruit in samples of Marsh seedless grapefruit, by size of fruit, 1953-54, 1954-55, 1956-57, and 1957-58

Fruit size	Fall harvest			Spring harvest		
	Seedless	Seedy	Pink	Seedless	Seedy	Pink
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
96..............	97	3	0	99	1	0
80..............	99	([1])	([1])	98	2	0
70..............	100	0	0	99	1	0
64..............	93	2	5	97	3	0
54..............	97	1	2	95	5	0
46..............	87	4	9	92	8	0

[1] Less than 0.5 percent.

TABLE 6.--Volume of juice yielded by Marsh grapefruit, by size of fruit, 1953-54, 1954-55, 1956-57, and 1957-58

Fruit size	Fall harvest		Spring harvest		Legal maturity requirements[1]		
	Range	Average	Range	Average	Aug. 1 through Oct. 15	Oct. 16 through March 1	March 2 through July 31
	Milliliter	*Milliliter*	*Milliliter*	*Milliliter*	*Milliliter*	*Milliliter*	*Milliliter*
96................	124-276	200	157-288	220	185	180	170
80................	147-344	226	169-327	249	210	200	190
70................	171-322	246	159-367	270	230	220	210
64................	173-367	271	174-397	291	255	240	230
54................	209-382	299	209-458	329	280	270	255
46................	230-448	340	241-519	368	320	305	290

[1] From "The Florida Citrus Code of 1949, as Amended", Florida Citrus Commission, 1957.

Some of the variations in juice volume of individual grapefruit of the different sizes are brought out by observing the shape of the curves in figure 3. While the greatest proportion of the values occurs in the midclass, 44 to 65 percent of the fruits harvested in the fall fell into classes above or below this class, with more usually below. There was a distinct tendency in the larger sizes for a higher percentage of fruits to be in the extreme classes, as is shown by the flatter curve. Somewhat the same pattern was apparent in the spring samples, except that a higher proportion of the fruits had more juice than those in the midclass instead of less juice, causing the curves to shift to the right. This trend was accentuated in size 46 where the highest percentage of fruits was in the class just above the average.

Variations in average juice volume for fruits sampled in the 1954-55, 1956-57, and 1957-58 seasons are shown in table 7. Grapefruit harvested in the spring of the 1954-55 season had from 6 to 28 ml. more juice than those in 1956-57, while fruits harvested in the fall of 1956-57 contained from 25 to 49 ml. less juice than those in 1957-58. In the 1956-57 season the fruits had relatively smaller amounts of juice than in either 1954-55 or 1957-58. This may be attributed to the fact that 1956-57 was a year of lower rainfall than the other two.

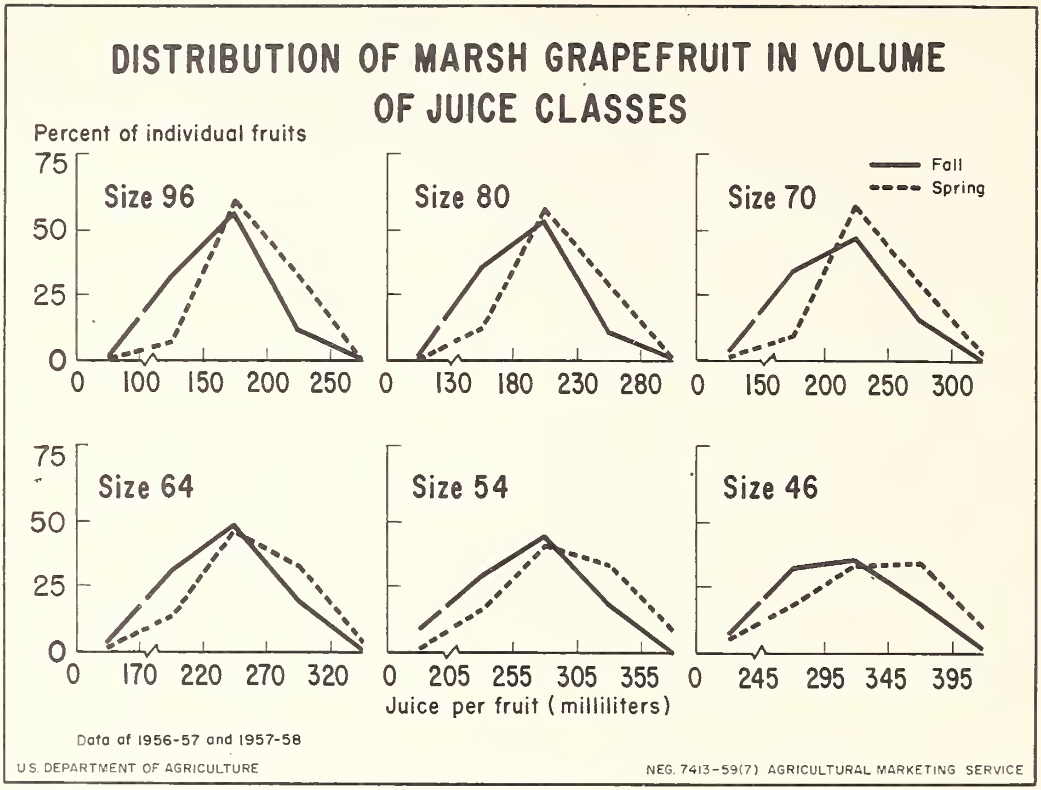

FIGURE 3

When the juice volume of Marsh grapefruit harvested in the fall and spring was compared with the legal maturity requirements it was found that some of the fruits did not meet the requirements. From 40 to 92 percent of the individual fruits collected in October 1956, and 24 to 52 percent of those in September 1957 failed to meet juice requirements (table 8). In October 1956, the average juice volume of the fruit of each size also failed, while in September 1957 only that of size 96 was below the minimum standard. Samples collected in October 1957 had from zero to 36 percent of the fruits of a size in this category. In the samples of May 17, 1955, and March 5, 1957, up to 40 percent of the fruits harvested failed to meet the volume of juice requirements. Table 9 shows the amount by which the average juice volume of the samples was below or above the requirement.

Differences between the low and high values for fall samples of 58 to 87 percent of the average volume of juice were found as compared to 60 to 78 percent for spring fruit. Greater variation occurred in the smaller sizes in the fall and in the larger sizes in the spring.

These data illustrate the extreme difficulty in securing samples which are truly representative. All of the fruit were obtained from bins out of lots from which Federal-State inspectors (Florida Department of Agriculture and U. S. Department of Agriculture cooperating) had drawn samples for tests of maturity and grade. Obviously they were found mature from a legal standpoint or they would have been condemned. With a few possible exceptions, such as perhaps the fruit of sizes 64 and 54 of the sample collected October 2, 1956, all of the below-standard samples were borderline cases in which slight variations in the technique used for extraction of the juice, human errors, or variability of the fruit could readily account for the discrepancy.

TABLE 7.--Average volume of juice per fruit of Marsh grapefruit by size of fruit, by time of harvest and crop year, 1954-55, 1956-57, and 1957-58

Fruit size	1954-55	1956-57		1957-58
	March, April, May[1]	October[2]	March, April, May[3]	September, October[4]
	Milliliter	*Milliliter*	*Milliliter*	*Milliliter*
96..........	227	175	215	200
80..........	259	196	241	226
70..........	280	212	262	246
64..........	294	235	288	271
54..........	342	251	321	299
46..........	385	291	357	340

[1] 150 fruits tested.
[2] 50 fruits tested.
[3] 200 fruits tested.
[4] 150 fruits tested.

TABLE 8.--Percentage of Marsh grapefruit not meeting the requirements of the Florida Citrus Code for volume of juice, by time of harvest, date of sampling, and size of fruit, 1955-56, 1956-57, and 1957-58[1] [2]

Fruit size	Fall dates of sampling						
	Oct. 2, 1956	Oct. 23, 1956	Sept. 24, 1957	Oct. 3, 1957	Oct. 24, 1957	Oct. 29, 1957	Oct. 29, 1957
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
96.......	[3] 76	[3] 72	[3] 44	20	0	36	4
80.......	[3] 88	[3] 52	48	4	0	20	0
70.......	[3] 72	[3] 68	48	0	0	20	8
64.......	[3] 92	[3] 40	52	4	8	16	16
54.......	[3] 88	[3] 72	24	12	8	8	4
46.......	---	[3] 68	36	32	28	20	0

Fruit size	Spring dates of sampling							
	April 4, 1955	April 7, 1955	May 17, 1955	May 24, 1955	March 1, 1957	March 5, 1957	April 17, 1957	May 24, 1957
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
96.....	0	0	24	0	0	4	0	0
80.....	0	4	12	4	0	4	0	16
70.....	0	0	12	0	4	12	0	0
64.....	6	0	20	0	0	16	4	8
54.....	9	0	4	0	0	16	0	0
46.....	---	0	8	8	8	40	4	24

[1] Based on requirements of the Florida Citrus Code of 1949, as Amended.
[2] All samples of grapefruit taken on March 28 and May 25, 1955 March 13 (2 samples), April 1, and May 23, 1957, and Oct. 29, 1957 met the requirements.
[3] Average volume for the 25-fruit subsample was below the amount required.

TABLE 9.--Percentage of Marsh grapefruit exceeding, by specified amounts, requirements of Florida Citrus Code for yield of juice by size of fruit, 1956-57 and 1957-58[1]

Fruit size	Grapefruits exceeding requirements by--				Grapefruits not meeting requirements
	1-10 ml.	11-20 ml.	21-30 ml.	31 ml. or more	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
96...........	17	11	13	44	15
80...........	9	15	16	36	24
70...........	13	8	11	44	24
64...........	6	9	10	48	27
54...........	3	11	11	49	26
46...........	11	8	4	54	23

[1] Based on requirements of the Florida Citrus Code of 1949, as Amended.

Chemical Analyses

Total Soluble Solids.--Total soluble solids in Marsh grapefruit harvested in the fall ranged from 7.2 to 12.2 percent, while those of the spring samples varied from 6.1 to 15.1 percent (table 10). Average values for solids decreased in fruits of size 96 to size 46, with a few exceptions. These results agree with those of Harding and Lewis (16) who found higher total soluble solids in smaller oranges than in larger ones. Fruits harvested in the spring contained 0.3 to 0.4 percent higher total soluble solids than those in the fall samples. The maximum values found for grapefruit harvested in the spring were from 1.7 to 3.5 percent higher in soluble solids than those in the fall samples. Harding and Fisher (15) have shown that total soluble solids gradually increase as the season progresses. Lower minimum values were obtained in the spring samples, presumably because of the presence of late-bloom fruit. Only a few fruits, principally those of size 46, failed to meet legal maturity requirements.

The variability of percent total soluble solids in grapefruit of the several sizes is shown graphically in figure 4. It can be noted that 40 to 65 percent of the fruits harvested in the fall fell into the midclass, but only 25 to 35 percent of the spring samples were in this group. There was a fairly consistent trend between percent of fruits in the midclass and size. Invariably, there were lower percentages of fruits of sizes 96 or 80 than of sizes 70 or 64 or of sizes 54 or 46 in the midclass and proportionately more in the highest class. This trend was more pronounced in the fall samples than in the spring samples.

The most important component of citrus fruits is the soluble constituents of the juice which are collectively measured as total soluble solids. While total soluble solids are chiefly sugars (sucrose, glucose, and fructose), they also include organic acids, vitamin C, vitamin A, salts, proteins, glucosides, essential oils, and other compounds. The flavor and aroma of grapefruit juice is derived from them. In Florida total soluble solids have been used as a part of the maturity standard for grapefruit since 1925. The present total solids requirements for white seedless grapefruit are a minimum of 7.5 percent total soluble solids from August 1 through December 31 and 7.0 percent from January 1 through July 31. Solids, together with total soluble solids-to-acid ratio, and volume of juice are the only maturity standards in many citrus areas of the world.

Percent total solids did not vary as greatly on a percentage of the average basis as some of the other constituents. The differences between the minimum and maximum values ranged from 39 to 47 percent of the average values for the different sizes of fall fruit samples, while spring fruit samples varied from 56 to 88 percent on a similar basis. The 1.5 to 2.0 percent variation in soluble solids content below the average found in fall fruit affects palatability. Values for spring samples differed considerably more than fall samples ranging from 2.8 to 3.3 percent below to 2.1 to 5.1 percent solids above the average value. The variation was not related to size.

TABLE 10.--Total soluble solids content of Marsh grapefruit, by size of fruit, 1953-54, 1954-55, 1956-57, and 1957-58

Fruit size	Fall harvest		Spring harvest		Fruit below requirements[1]	
	Range	Average	Range	Average	Fall	Spring
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
96.........	7.73-11.67	9.56	7.10-12.70	9.97	0	0
80.........	7.73-12.17	9.50	6.80-12.87	9.78	0	1
70.........	7.23-11.47	9.51	6.58-15.06	9.67	1	2
64.........	7.81-11.47	9.34	6.73-13.60	9.74	0	1
54.........	7.64-11.25	9.23	6.05-13.06	9.40	0	2
46.........	7.31-10.93	8.88	6.05-13.06	9.26	1	5

[1] The Florida Citrus Code of 1949, as Amended, Florida Citrus Commission, 1957.

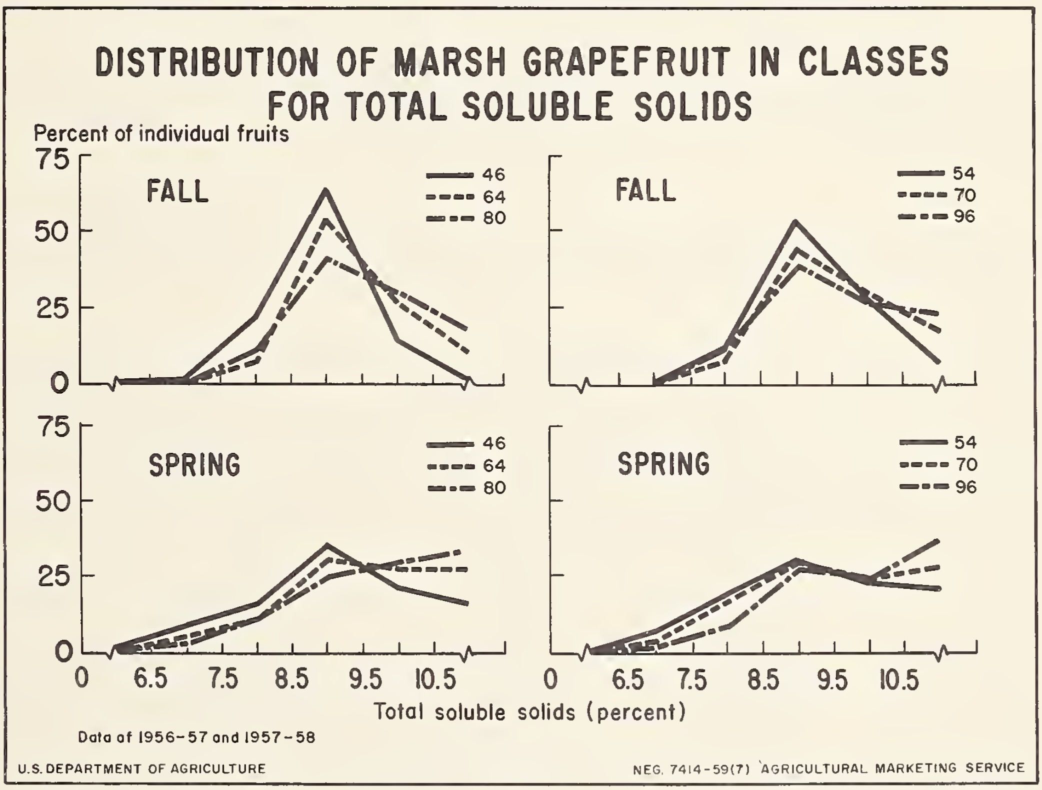

FIGURE 4

Acid Content.--The total acid content of Marsh grapefruit harvested in the fall ranged from 0.64 to 1.76 percent, while the spring samples varied from 0.33 to 1.89 percent (table 11). Fruits of size 96 had slightly more acidity on the average than those of other sizes. There was a consistent trend for smaller fruits to contain higher percent acid than large fruits. The extent of the variations among individual fruit of different sizes is shown in figure 5. Not only were there more grapefruit of the fall samples in the average class or that next above it, but the distribution of fruits over the entire group of classes was also quite different from the spring samples. There was a distinct shift in the spring samples toward the lower end of the scale, particularly in size 96.

While the differences between the minimum and maximum acid percentage ranged from 0.9 to 1.1 percent, this constituted 77 to 93 percent of the average amounts observed. Percentage differences for spring fruit were equal to 119 to 131 percent of the average. No relation was noted for fruit size.

The acceptance of grapefruit as a food is based largely on the proportion of sugars to acid in the juice. The normal decrease in acidity which occurs as the season progresses may be accelerated somewhat through the use of arsenical sprays of low concentration to reduce the acidity of fruits picked during the middle of the season or of higher concentration to permit harvest for the early market in the fall. Arsenical sprays enable growers and shippers to extend the marketing season and to produce fruit having higher solids-to-acid ratio earlier in the season (9, 13, 15, 23, 26).

Ratio of Total Soluble Solids to Total Acid.--The minimum, maximum, and average solids-to-acid ratios of fall samples of Marsh grapefruit are shown in table 12. Individual fruits of sizes 96, 80, and 54 had the lowest solids-to-acid ratios, while size 96 had the highest.

Grapefruit harvested in the spring did not exhibit the same regularity in solids-to-acid ratio as in the fall. The lowest ratio encountered was in size 54, 5.8 to 1, while the highest ratio was in size 46, 25.7 to 1. The range in solids-to-acid ratio was widest in size 46 and narrowest in size 96.

TABLE 11.--Total acid of Marsh grapefruit, by size of fruit, 1953-54, 1954-55, 1956-57, and 1957-58

Fruit size	Fall harvest		Spring harvest	
	Range	Average	Range	Average
	Percent	*Percent*	*Percent*	*Percent*
96............	0.64-1.76	1.21	0.58-1.89	1.04
80............	.69-1.61	1.19	.51-1.72	1.02
70............	.74-1.66	1.20	.45-1.72	.97
64............	.75-1.63	1.15	.49-1.74	.98
54............	.67-1.60	1.12	.45-1.60	.93
46............	.66-1.62	1.07	.33-1.51	.90

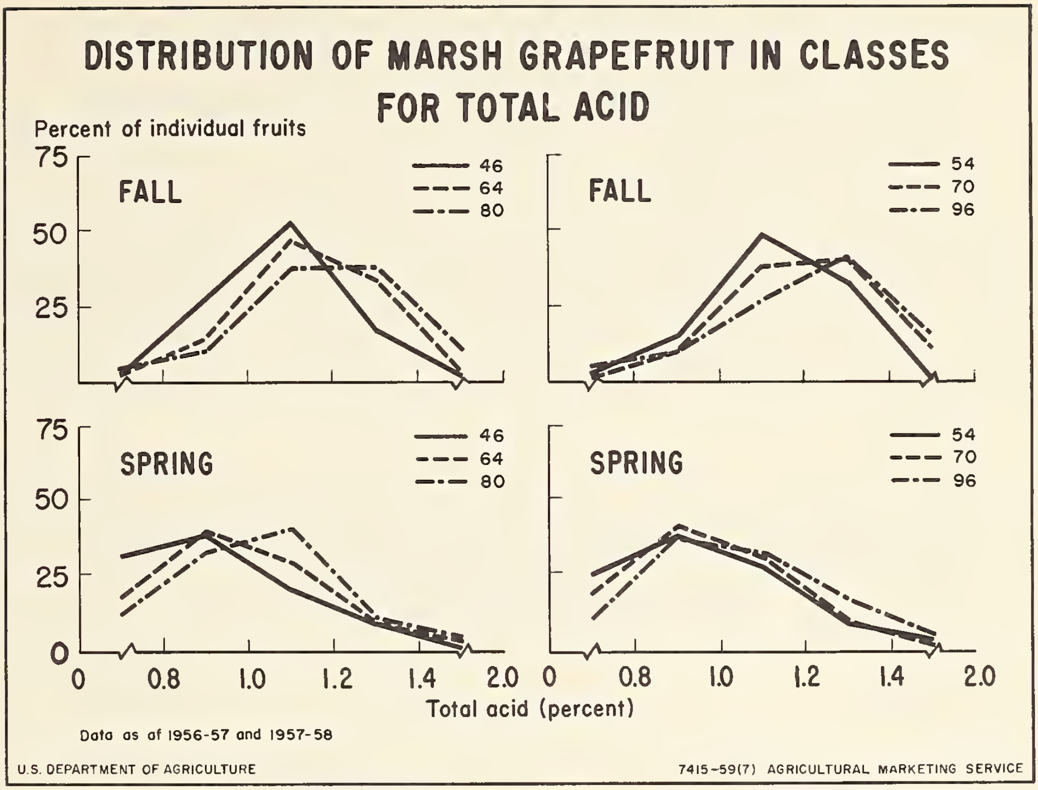

FIGURE 5

There were striking differences when the solids-to-acid ratios of the individual grapefruits were grouped into classes as seen in figure 6. The samples harvested in the fall fell in two distinct groups. A greater proportion of the fruits in sizes 96, 80, and 70 were in the 7.00-7.99 to 1 ratio class, while a greater proportion of sizes 64, 54, and 46, were in the 8.00-8.99 to 1 ratio class. The proportion of fruit of the spring samples in the various ratio classes was quite different as the range in solids-to-acid ratios was much wider, and there were consequently fewer fruit in any one class.

Very few fruit were found to have a solids-to-acid ratio below the legal maturity standard--only 1 percent of the sizes 96 and 80 failed to meet the requirements.

In many citrus areas of the world the ratio of total soluble solids to total acid is the principal standard for maturity of citrus fruits including grapefruit. It has also been one part of the standard for maturity in Florida for many years. A sliding ratio is employed for Florida grapefruit instead of a flat 6 to 1 or 5.5 to 1 solids-to-acid ratio as used in California. The sliding ratio is based on the concept that fruits that contain low total soluble solids must also have a low acid, hence a high ratio; whereas those with high total soluble solids could have high acid, and a lower ratio, to be palatable. The present requirements for solids-to-acid ratio of white seedless grapefruit in Section 601.17 of the Florida Citrus Code of 1949, as Amended, provide for a stepwise decrease from 7 to 1 with solids of 6.5 to 9 percent to 6 to 1 with solids of 12 percent and over. During the period from August 1 through April 14, there is a minimum required solids-to-acid ratio which depends upon the percent total soluble solids. From April 15 through July 31, the minimum solids-to-acid ratio is 6 to 1.

TABLE 12.--Total soluble solids-to-acid ratio of Marsh grapefruit, by size of fruit, 1953-54, 1954-55, 1956-57, and 1957-58

Fruit size	Fall harvest			Spring harvest		
	Minimum	Maximum	Average	Minimum	Maximum	Average
96.........	5.9 to 1	13.4 to 1	7.9 to 1	6.0 to 1	16.2 to 1	9.6 to 1
80.........	5.9 to 1	12.5 to 1	8.0 to 1	6.3 to 1	18.9 to 1	9.6 to 1
70.........	6.0 to 1	12.4 to 1	7.9 to 1	6.8 to 1	21.0 to 1	10.0 to 1
64.........	6.2 to 1	11.2 to 1	8.1 to 1	6.1 to 1	20.9 to 1	9.9 to 1
54.........	5.9 to 1	12.4 to 1	8.2 to 1	5.8 to 1	20.6 to 1	10.1 to 1
46.........	6.0 to 1	11.7 to 1	8.3 to 1	7.0 to 1	25.7 to 1	10.3 to 1

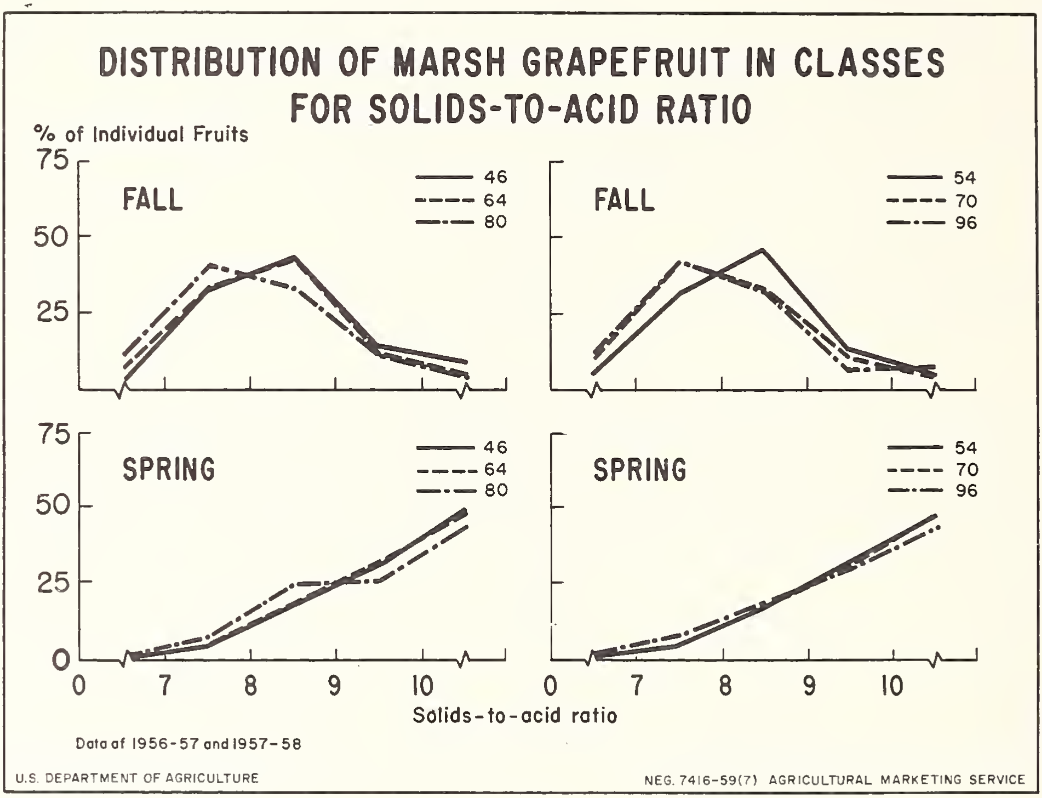

FIGURE 6

The differences between the extremes for fall samples ranged from 5.0 to 7.5 ratio points, and from 10.2 to 18.7 points for spring samples. In other words, variations ranged from 62 to 95 percent of the average values for fall and from 106 to 181 percent for spring fruit. No relation was noted to size in fall samples, but the percentage was greater in larger sizes of spring fruit.

Ascorbic Acid (Vitamin C).--Grapefruit, like other citrus fruits, are a valuable source of ascorbic acid (vitamin C). This constituent is quite variable, as it is affected by numerous environmental factors of which perhaps the most important are the degree of exposure of the fruit to light and age of fruit from bloom.

As may be seen in table 13, Marsh grapefruit harvested in the fall contained from 29 to 58 mg. of ascorbic acid per 100 ml. of juice, with average values ranging from 37 to 41 mg. per 100 ml. Fruit of size 96 were somewhat more variable than those of other sizes. There was a slight but distinct tendency for this variability to become less from the smallest size to the largest size. Smaller sizes of fruit had significantly greater concentrations than larger sizes (19).

Samples harvested in the spring contained from 26 to 57 mg. of ascorbic acid per 100 ml. of juice. The average concentration of ascorbic acid dropped steadily from 39 mg. per 100 ml. for size 96 to 35 mg. for sizes 54 and 46. The greater variability of ascorbic acid in the spring samples probably resulted from the late-bloom fruit, less mature fruit, and overripe fruit which were present. Differences between the extreme concentrations of ascorbic acid were found to be 20 to 28 mg. per 100 ml. of juice in the fall samples and 30 to 33 mg. per 100 ml. in spring samples. These correspond to 51 to 70 percent of the average concentrations for the fall fruit and 79 to 92 percent in the spring samples.

pH (Active Acidity).--The changes in pH, although small, roughly paralleled the decrease in total or titratable acid. Determinations of pH were made on composite samples of juice rather than on individual Marsh grapefruit of each size, and in no case was there a difference of more than 0.3 pH unit from the average value for the 6 sizes comprising a complete sample. The average pH values of all of the grapefruit harvested in the fall ranged within 0.1 pH unit of those collected in the spring. Likewise, the differences from one season to another were minor.

TABLE 13.--Ascorbic acid concentrations in Marsh grapefruit juice, by size of fruit, 1954-55, 1956-57, and 1957-58[1]

Fruit size	Fall harvest			Spring harvest		
	Minimum	Maximum	Average	Minimum	Maximum	Average
	Mg. per 100 ml.	*Mg. per 100 ml.*	*Mg. per 100 ml.*	*Mg. per 100 ml.*	*Mg. per 100 ml.*	*Mg. per 100 ml.*
96.........	30	58	40	26	57	39
80.........	30	55	40	25	55	38
70.........	32	54	40	24	57	37
64.........	30	54	41	23	56	36
54.........	30	50	39	24	55	35
46.........	29	49	37	21	51	35

[1] Ten individual fruits of each sample were analyzed for ascorbic acid instead of 25 fruits as used for the other tests.

Interactions between Physical and Chemical Components

The variation of any one constituent among individual Marsh grapefruit is quite great; however, certain interrelations can be shown to exist.

Strong interrelations are apparent among fruit weight, fruit diameter, volume of juice, and internal texture (figs. 7 and 8). Graphical analysis using scatter diagrams and symbols for different internal textures shows that the points tend to form a straight line. The more closely these points fall along a line, the stronger the existing correlation. This also emphasizes that good-textured fruit of the same diameter usually yield more juice and are heavier than coarse- or ricey-textured fruit. This effect is not so apparent

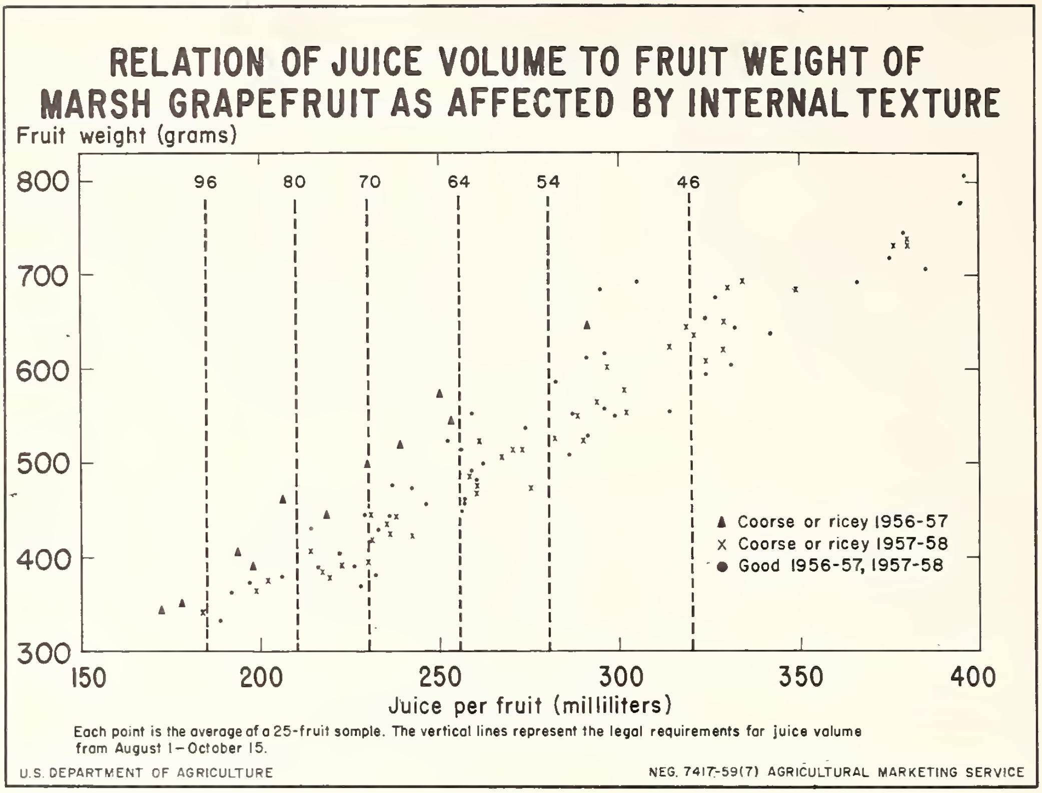

FIGURE 7

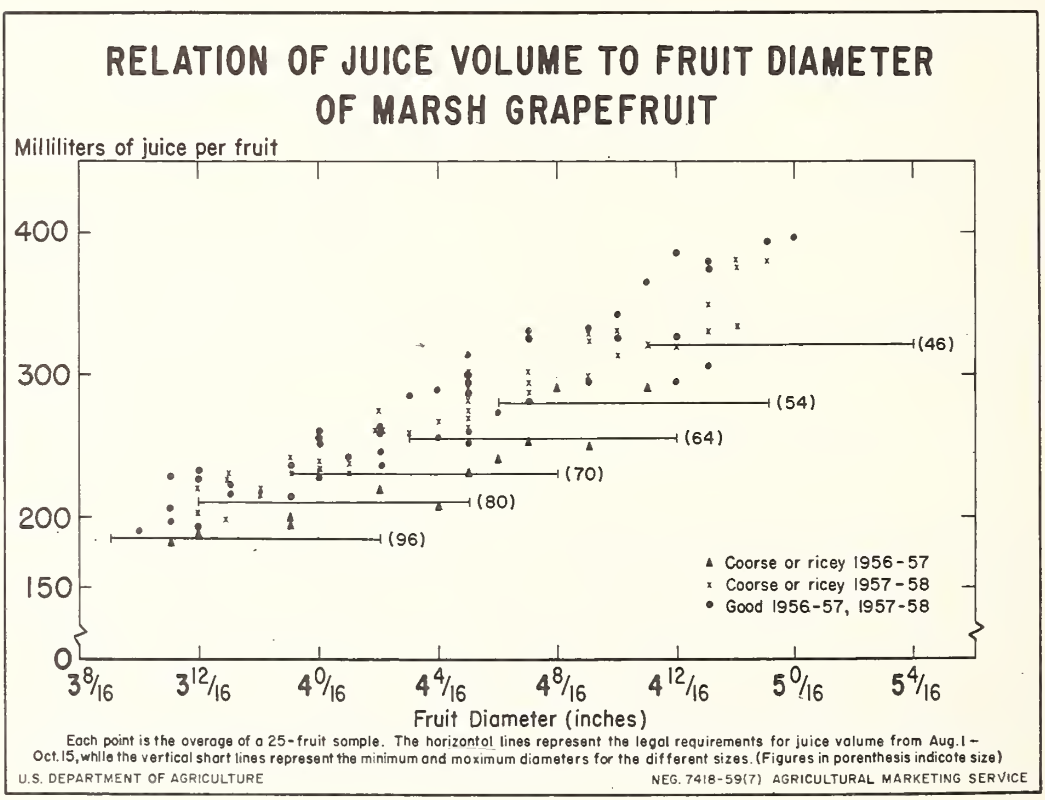

FIGURE 8

in those years when the volume of juice is high, such as 1957-58. Conversely, ricey- or coarse-textured fruit would have more difficulty passing the juice requirements, especially in years of low volume of juice (fig. 8). The overlapping of the diameters of the different sizes is also shown in figure 8.

The relationships of the observed average volumes of juice and average diameters for the samples to the requirements specified by the Florida Citrus Code of 1949, as amended (10), and the Regulations of the Florida Citrus Commission (11), are shown in figure 9. Fall samples yielded 10 to 30 ml. more than the volume required, which is equivalent to about 10 percent. Spring fruit averaged 55 to 100 ml. more juice than the requirements, which is in excess of 20 percent. Size 70 of the fall samples appeared to surpass the volume requirements with less margin than the other sizes.

Similar relationships have not been observed between chemical factors or between chemical and physical factors. When the percent total soluble solids is plotted against volume of juice (fig. 10), a fairly distinct separation between those samples of fruit which are coarse- and ricey- and those which are good-textured seems to exist at about 9.5 percent soluble solids. Similarly, if percent total acid is plotted against volume of juice (fig. 11), a distinct break occurs between 1.00 and 1.02 percent. When the ratio of total solids to total acid is used (fig. 12), the separation occurs above 8.75 to 1 ratio. All of the exceptions in the total acid or solids-to-acid ratio graphs were for fall samples from 1957-58, a year when the volume of juice and ratio were higher than average and soluble solids and acid were lower (15).

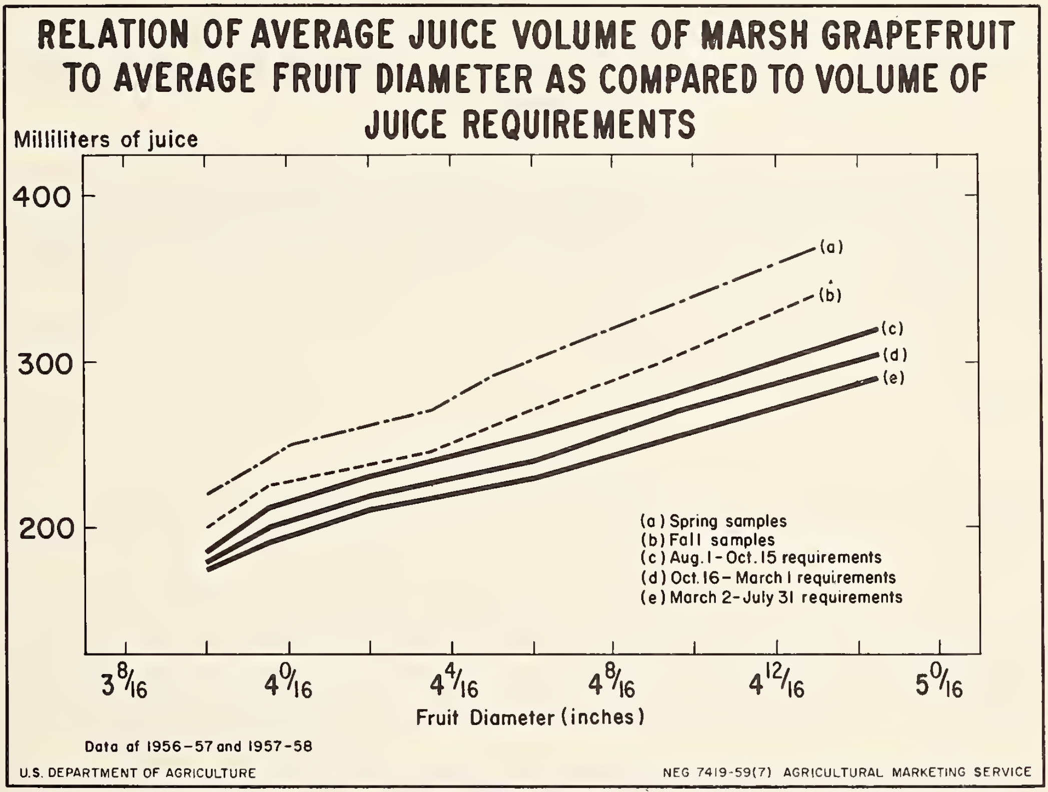

FIGURE 9

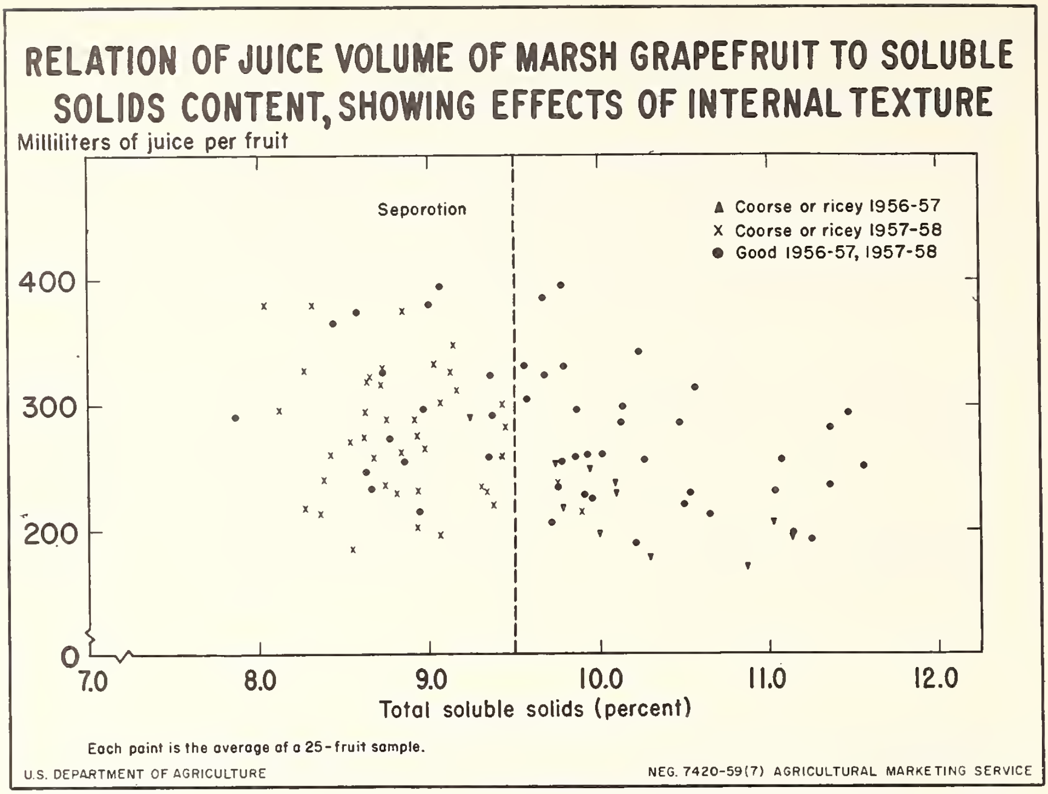

FIGURE 10

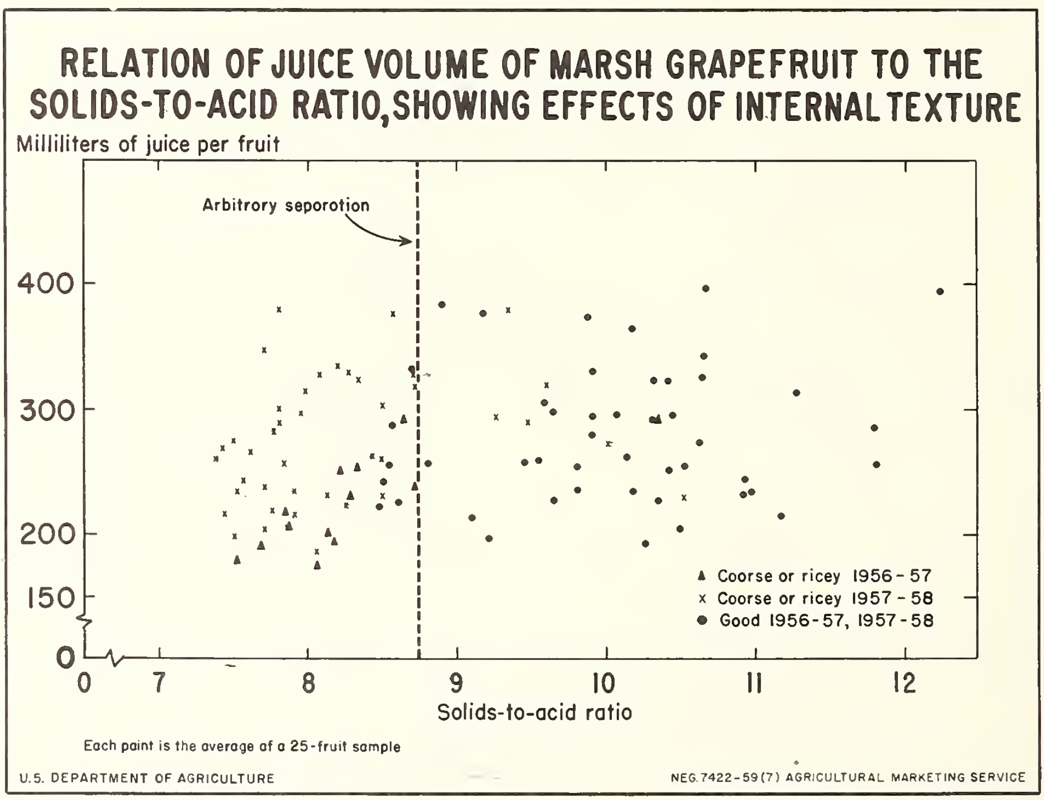

FIGURE 11

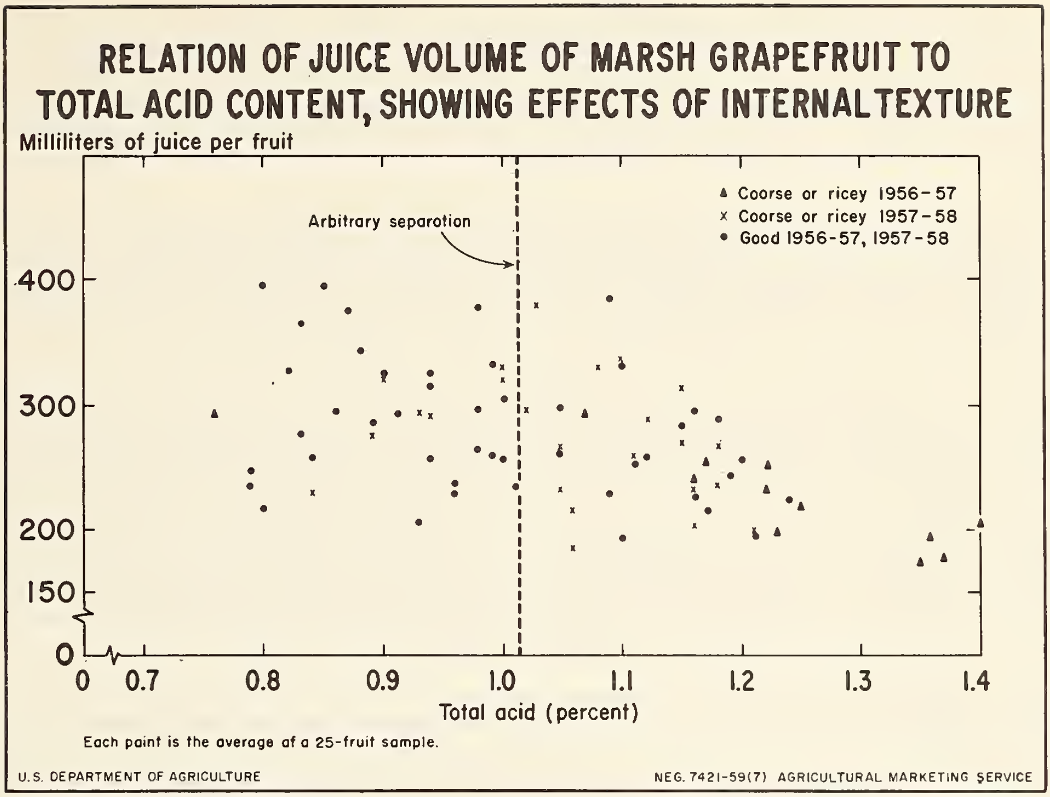

FIGURE 12

When percent juice was calculated for the data obtained in 1956-57 season, it was found that it increased slowly to a maximum in March and April and decreased fairly rapidly in late May to a level that was about the same as in the previous October. In 1957-58 the percent juice attained a higher level and much earlier in the season.

The density of the juice varied from 1.01 to 1.04 with the preponderance showing 1.02 or 1.03. The variation was small between samples, sizes, fall or spring season, and crop years.

DISCUSSION

Based upon the data obtained, several possibilities seem to exist that may help to eliminate or control some of the variations and assist in the upgrading of the pack of grapefruit.

Those fruit which are much below the others in quality can sometimes be eliminated by their particular weakness. For instance, a fruit which is low in juice, poor in texture, or thick-rinded is usually lighter in weight than a fruit of the same diameter having high volume of juice, good texture, and a thin rind. Thus a combination of weight and sizing would keep some undesirable fruit from going into the bins.

Since specific gravity varies (27, 28), the light fruit separators now used for separation of frozen and good fruit by flotation might be adapted to provide a way to separate heavy and light fruit. However, research would be necessary upon this aspect to see whether or not this method is applicable and feasible.

In order to improve the grapefruit pack, juice requirements could be increased on fresh grapefruit during September, October, and November. The data in figure 9 indicate that an increased juice requirement would pose no great problem on this score. However, it should be pointed out that the increase should be moderate because of lower-than-normal volumes of juice encountered during certain crop years. From these data it would appear that the volume of juice might be increased 5 percent with beneficial results.

Since 3 sizes theoretically could be packed out of any one bin (fig. 9), a fruit which fails to meet the juice requirement as one size could be shipped as one size smaller. Improvements in the sizing equipment would be necessary to secure more uniform size and eliminate individual fruits which may not meet the juice requirement because of their small size.

Since one of the most frequent objections to grapefruit is its acidity or tartness, one of the most logical ways to improve quality would seem to be increasing the solids or solids-to-acid ratio. However, since it is acidity that is concerned, it might be desirable to establish a maximum permissible percent acid. A fairly definite separation occurs between coarse or ricey and good fruit at certain levels of solids, acid, and solids-to-acid ratio. If these breaks (figs. 10, 11, 12) are to be used the proper levels would appear to be 9.0 to 9.5 percent minimum solids, 1.0 to 1.1 percent maximum acid, and a solids-to-acid ratio of 8.5 to 1 or 9 to 1. In addition, the use of a minimum percent solids and a maximum percent acid would eliminate the necessity of calculation (and chance for error) involved with ratio.

It is obvious that when the fruit is picked to pass a certain minimum standard on an average or composite basis, some will be below, some near the value required, and some above the standard. The data reported here show this to be the case. Individual fruit analyses of a small sample would appear to be preferable to analyses of small composited samples of juice, since individual analyses would show the low quality fruit that cause unfavorable response when it reaches the consumer, while composites would conceal them.

LITERATURE CITED

(1) Association of Official Agricultural Chemists.

1955. Official Methods of Analysis. Ed. 8, Assoc. Off. Agr. Chem. Washington, D. C.

(2) Baier, W. E.

1932. Maturity Studies of California and Arizona Marsh Grapefruit. Cal. Citrog. 17:94 (Jan.)

(3) ____________

1954. The Pritchett Tongue. Cal. Citrog. 39(12):442.

(4) Bell, H. P.

1955. Preferences for Canned Grapefruit Juices. Fla. State Hort. Soc. Proc. 68:151-155.

(5) Bessey, O. A., and King, C. G.

1933. The Distribution of Vitamin C in Plant and Animal Tissues, and Its Determination. Jour. Biol. Chem. 103:687-698.

(6) Branson, R. E., Jacobs, M., and Hall, R.

1955. Frozen Grapefruit Sections: Evaluating a New Product by Retail Sales Audit and Household Survey. Mktg. Res. Rpt. 110, U. S. Dept. Agr., Agr. Mktg. Serv., 62 pp.

(7) Bureau of Agricultural Economics.

1951. Consumer Use of and Opinions About Citrus Products. Agr. Inform. Bul. 50, U. S. Dept. Agr., 167 pp.

(8) Capel, G. L.

1955. The Quality of Florida Grapefruit in "A Discussion of Problems of the Florida Grapefruit Industry." Special Report to Fla. Citrus Mutual, Univ. of Fla., Gainesville, Fla.

(9) Deszyck, E. J., Reitz, H. J., and Sites, J. W.

1952. Effect of Copper and Lead Arsenate Sprays on the Total Acid and Maturity of Duncan Grapefruit. Fla. State Hort. Soc. Proc. 65:38-42.

(10) Florida Citrus Commission.

1957. State of Florida Citrus Fruit Laws. Florida Citrus Code of 1949, as Amended. 44 pp.

(11) ____________

1957. Regulations Pursuant to the Florida Citrus Code of 1949.

(12) Florida Department of Agriculture.

1957. Annual Report of Citrus and Vegetable Inspection Division. 1956-57 Season. 75 pp.

(13) Harding, P. L.

1945. Effect of Lead Arsenate Spray on the Seasonal Changes in Florida Grapefruit. Fla. State Hort. Soc. Proc. 58:161-169.

(14) __________

1952. Evaluating Palatability in Florida Citrus Fruits. Amer. Soc. Hort. Sci. Proc. 59:303-306.

(15) __________ and Fisher, D. F.

1945. Seasonal Changes in Florida Grapefruit. U. S. Dept. Agr. Tech. Bul. 886, 100 pp., illus.

(16) __________; and Lewis, W. E.

1941. The Relation of Size of Fruit to Solids, Acid, and Volume of Juice in the Principal Varieties of Florida Oranges. Fla. State Hort. Soc. Proc. 54:52-56.

(17) Hilgeman, R. H.

1941. Studies on the Ripening of Marsh Grapefruit in Arizona with Especial Reference to the Improvement of Maturity Measurements. Ariz. Agr. Expt. Sta. Tech. Bul. 89.

(18) Jones, W. W., and Parker, E. R.

1949. Effects of Nitrogen, Phosphorus, and Potassium Fertilizers and of Organic Materials on the Composition of Washington Navel Orange Juice. Amer. Soc. Hort. Sci. Proc. 53:91-102.

(19) Long, W. G., Harding, P. L., and Soule, M. J., Jr.

1957. The Ascorbic Acid Concentration of Grapefruit of Different Sizes. Fla. State Hort. Soc. Proc. 70:17-21.

(20) Production and Marketing Administration.

1952. U. S. Standards for Florida Grapefruit. U. S. Dept. Agr. 13 pp.

(21) Provan, J. L.

1936. Grapefruit Analyses: Impossible to Fix Maturity Standards So Far. Citrus News. 12:57-58.

(22) Reuther, W., and Smith, P. F.

1951. Relation of Fertilizer Treatment to Fruit Quality of Valencia Oranges. Fla. State Hort. Soc. Proc. 64:29-35.

(23) Rygg, G. L., and Getty, M. R.

1955. Seasonal Changes in Arizona and California Grapefruit. U. S. Dept. Agr. Tech. Bul. 1130, 44 pp.

(24) Shuler, P. E., and Townsend, J. C., Jr.

1957. Florida Citrus Fruit; Annual Summary 1957. U. S. Dept. Agr., Agr. Mktg. Serv., and Fla. Dept. Agr. 10; 48 pp.

(25) Sinclair, W. B., and Bartholomew, E. T.

1947. Compositional Factors Affecting the Edible Quality of Oranges. Amer. Soc. Hort. Sci. Proc. 50:177-186, illus.

(26) Sites, J. W.

1947. Internal Fruit Quality as Related to Production Practices. Fla. State Hort. Soc. Proc. 60:55-62.

(27) Turrell, F. M., Carlson, J. P., and Klotz, L. J.

1945. Surface and Volume Determinations of Citrus Fruits. Amer. Soc. Hort. Sci. Proc. 46:159-165.

(28) ________ and Slack, D. L.

1948. Specific Gravity of Citrus Fruits. Amer. Soc. Hort. Sci. Proc. 52: 245-250.

(29) Wood, J. F., and Reed, H. M.

1938. Maturity Studies of Marsh Seedless Grapefruit in the Lower Rio Grande Valley. Tex. Agr. Expt. Sta. Bul. 562, 39 pp.